Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 85, 2014: 123-130
(Ann. WULS - SGGW, For. and Wood Technol. 85, 2014)

Radial growth of selected stands of black locust in Poland

MARCIN KLISZ[1], JOANNA UKALSKA[2], TOMASZ WOJDA[1], SZYMON JASTRZĘBOWSKI[1], MARCIN MIONSKOWSKI[3], IWONA SZYP-BOROWSKA[1]

[1]Forest Research Institute, Department of Silviculture and Genetics, Poland
[2]Warsaw University of Life Sciences, Faculty of Applied Informatics and Mathematics, Department of Econometrics and Statistics, Poland
[3]Forest Research Institute, Department of Forest Resources Management

Abstract: *Radial growth of selected stands of Black locust in Poland.* Within the framework of research being carried out in Poland on straight-stemmed populations of the black locust tree, it proved possible to identify three stands in west of the country suitable for further study on properties of the wood of this species. Subsequent analysis of radial profiles carried out on discs taken from ten sample trees (from each of the stands) allowed for the identification of two periods of growth (1990–1999 and 2000–2014) that are characterised by a different dynamic. At the same time, confirmation was offered for a significant influence of an interaction between the population factor and years, when it came to the shaping of annual growth rings, this pointing to both the individual- and population-level nature of the variability to radial growth in the species. Tree rings generated on the southern and eastern sides of the trunk are shown to be significantly wider than those on the northern and western sides. These regularities may reflect insolation, and the initiating influence of day length and temperature on cambial activity. Sample trees from the Krosno population do not display differentiation to the width of rings in relation to geographical orientation, this in turn most probably reflecting the shading influence on the trees exerted by Norway spruces in the second stand layer.
Keywords: Robinia pseudoacacia, growth eccentricity, growth pattern, repeated measures

INTRODUCTION

Across State Forests land in Poland, the black locust covers more than 273.000 ha, while with the greatest concentration of specimens in the Forest Districts in the west of the country [15]. Stands in which this species is dominant cover the largest areas within the Zielona Góra, Szczecin, Poznań and Wrocław Regional Directorates (respectively 2250, 1670, 960 and 820 ha). The stands in which trunks are of the best quality – i.e. straight – are concentrated in those Forest Districts in which the species attains the highest shares of the stand overall. Data from the General Directorate of the State Forests show that – for several years now – harvests of the species under study have been in the range 70-80.000 m^3 annually, with the trend being upward. While it is true that the main timber classes represented in wood obtained by clearcutting or shelterwood cutting is sawnwood in classes S2 and S4, the level of harvesting of roundwood is inadequate when set against the indicated demand. However, a tendency for this species to develop curved trunks in later life is a well-known feature [8, 9, 10], though the results of research carried out to date confirm the genetic basis for the development of straight-trunked forms in selected populations [10]. This in turn suggests a possibility for the quality of the raw timber produced being improved by way of the selection of particular genotypes [2, 4]. One of the anatomical features of trees conditioning this quality is a centralised location of the pith in the overall cross-section, this in turn reflecting the even production of growth rings in each direction. The broad scope of research carried out on what are qualitatively the best stands of black locust in Poland has *inter alia* taken in analysis of radial profiles. The work in question has in particular sought to point to regularities where the generation of off-centre cross-sections of the species is concerned.

MATERIALS

On the basis of data contained in the Central Information System of the State Forests, an analysis was carried out to determine the share by surface area of stands in which the black locust is dominant. Field study then allowed for the identification of seven stands for the species in which stem and trunk forms are predominantly straight. To meet the needs of analyses of radial profiles, timber properties and the structure of cambium and xylem, the final selection of stands was narrowed down to three – with these being located in the Mieszkowice, Krosno and Wołów Forest Districts (Fig. 1).

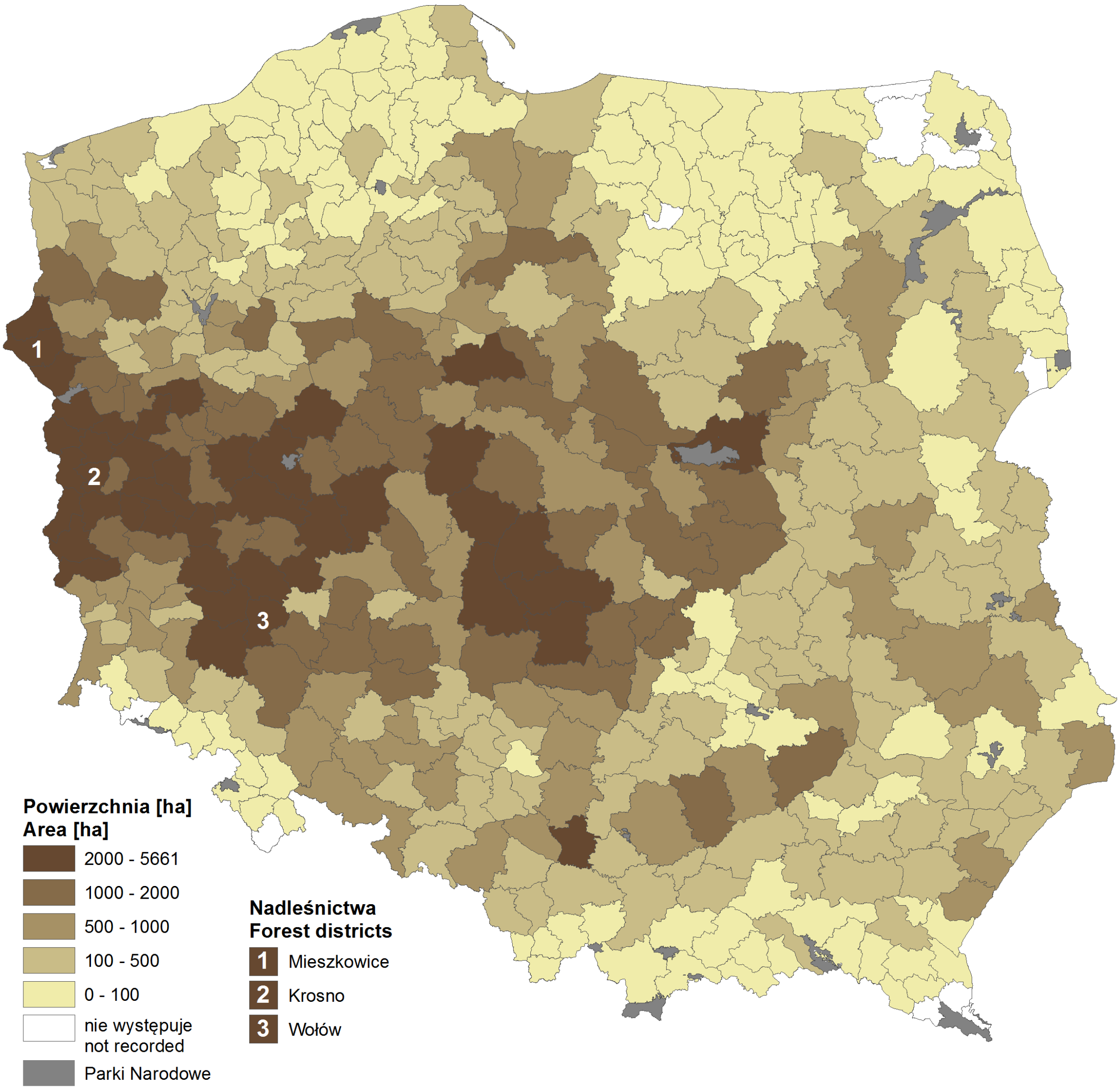

Fig. 1. Location of experimental sites: Mieszkowice, Krosno, Wołów.

The selected stands located in the west of Poland represent age classes IV and V. In each, a selection was made of some 10 trees from Kraft classes II and III, i.e. those characterised by a good state of health and the best trunk quality (Table 1).

Tab. 1. Locations and selected valuation traits of analysed stands

Forest District	Compartment	Area [ha]	Forest site type	Age	DBH [cm]	Total height [m]	Crown height [m]	Quality class	Stand stocking	Geographical position
Krosno	90b	1.14	LMśw	31	24.7	24.8	14.95	I	0.9	N 52 5 40.2 E 14 58 13.7
Wołów	194f	2.86	BMśw	38	21.1	22.7	13.5	I	0.8	N 51 25 12.5 E 16 34 41.8
Mieszkowice	210j	1.31	LMśw	46	26.0	24.5	13.3	I	1.0	N 52 51 31.5 E 14 11 40.7

Sample trees were cut down and discs from 1.3 m up the trunk sampled from the logs. Following polishing and scanning, the discs served in the further analysis of radial profiles for the four main compass directions, with the aid of the WinDENDRO 2009b program. Specifically, analysis took in the 25-year period of growth between 1990 and 2014, this allowing for radial profiles to be compared within a population of specimens of various ages. Comparison of the profiles as regards the width of rings in the analysed populations of black locust made use of ANOVA for multiple factors, in relation to repeated measurements, and following the model:

$$WR_{iju} = \mu + Y_i + P_j + \pi_{n(j)} + YP_{ij} + E_{ijn}$$

In turn, to show the influence of directional orientation on the shaping of ring widths, was used a statistical model taking account of the repeated factor of direction:

$$WR_{ijkn} = \mu + Y_i + P_j + \pi_{n(j)} + G_k + YP_{ij} + GP_{jk} + E_{ijkn}$$

where:

μ – the general mean,

Y_i – the year effect (repeated factor),

P_j – the population effect (non-repeated factor),

$\pi_{n(j)}$ – the effect of the n-th tree the j-th population (random effect),

G_k – the effect of the k-th direction (repeated factor),

YP_{ij} – the effect of the i-th year on the j-th population,

GP_{jk} – the effect of the k-th direction on the j-th population,

E_{ijn} – the random error for the n-th tree in the i-th year and the j-th population.

The analysis took into consideration the non-repeatable factor of population, as well as repeated factors like year and compass direction, and the interactions between them (year x population, compass direction x population). Because Mauchly's test rejected sphericity the significance of differences between populations, years and directions was verified using the multivariate measures: Wilks' lambda, Pillai's trace, Hotelling-Lawley trace and Roy's largest root [3]. A homogeneous group was then established in order that the width of annual rings might be compared for different compass directions. All statistical analysis were made using STATISTICA 10PL software [11].

RESULTS AND DISCUSSION

Analysis of the radial profiles of sample trees representing populations differing in terms of age allowed for the identification of two periods of radial growth among the three analysed groups of tree. The first 10-year period (extending between 1990 and 1999) is characterised by considerable differentiation to radial profiles in the populations studied, while in the second (15-year) period running from 2000–2014, there was some kind of blurring of differences between populations (Fig. 2). A similar regularity was identified by Adamopoulos and Voulgaridis [1], in 18-37 year-old trees growing at Chalkidiki (Greece). The results of the latter research point to the variability to growth rings being greatest in profiles closest to the basal part. Relatively low values for ring widths at the Mieszkowice site are most probably associated with cambial age (23–47), encompassing a period of stabilised growth characterising [5] the generation of maturing or mature wood, or else [7] mature wood. The course of the radial profile representing the youngest Krosno population (cambial age 8 – 31 years) is associated with the dynamic nature of growth in width in black locust trees during the period in question.

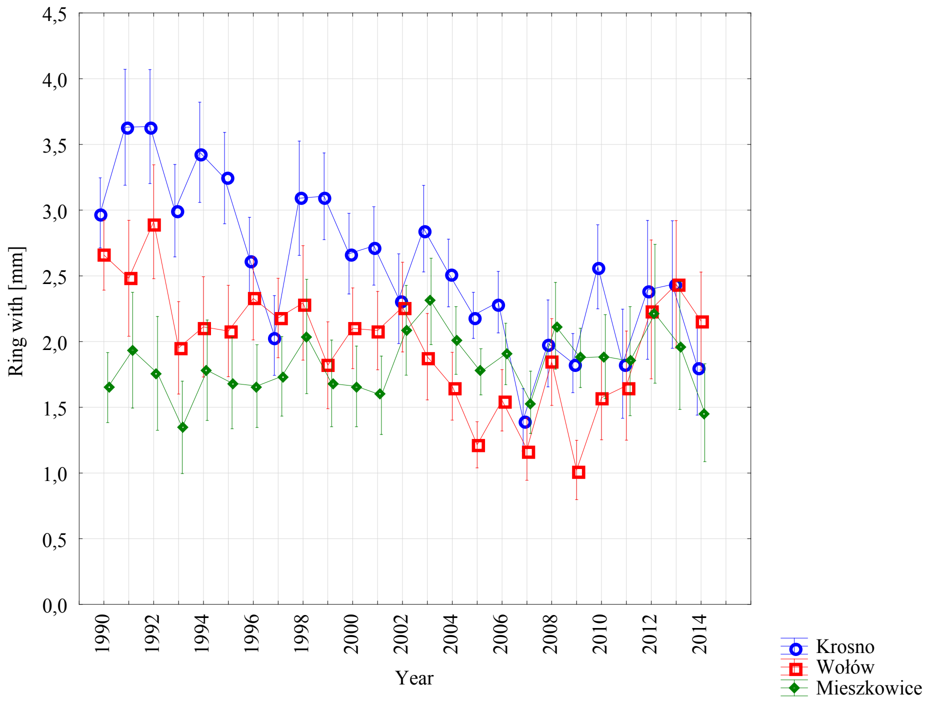

Fig. 2. Radial profiles for mean width values characterising growth rings in trees at the Krosno, Wołów and Mieszkowice sites.

Most statistical tests applied to determine the influence of the environment, the year (climatic factor variables) and geographical orientation on generated tree rings, as well as the interactions between these factors, have confirmed the statistically significant influence of the sources of variability referred to on ring widths (Table 2). The influence of specific growth conditions, and the combination of day length and temperature, on cambial activity in the black locust was confirmed in the work by Waisel and Fahn [14]. These conditions – which are variable through the growing season and in successive years – determine the generation of structures typical for early wood (large vessels) and late wood (fibres and parenchyma). In turn, the length of the period of generation of early and late wood determines the width of rings in cross-sections. The significant influence of the interaction between the factors of years and populations confirms observations made till now as regards individual- and population-level variability in the radial reaction of black locust trees to growth conditions [2].

Table 2. Analysis of variance for widths of annual growth rings as set against site, year of measurement and compass direction. df – degrees of freedom, MS – mean squares, F – F statistics, p – p-value.

Sources of variance	Test	numerator df	denominator df	MS	F	p
Year	Wilks'	24	3	0.005	23.827	0.0117
	Pillai's	24	3	0.995	23.827	0.0117
	Hotelling's	24	3	190.617	23.827	0.0117
	Roy's	24	3	190.617	23.827	0.0117
Year×Population	Wilks'	48	6	0.000	6.110	0.0148
	Pillai's	48	8	1.945	5.942	0.0059
	Hotelling's	48	4	133.749	5.573	0.0521
	Roy's	24	4	112.910	18.818	0.0056
Compass direction	Wilks'	3	24	0.503	7.897	0.0008
	Pillai's	3	24	0.497	7.897	0.0008
	Hotelling's	3	24	0.987	7.897	0.0008
	Roy's	3	24	0.987	7.897	0.0008
Geographical direction×Population	Wilks'	6	48	0.406	4.557	0.0010
	Pillai's	6	50	0.700	4.483	0.0011
	Hotelling's	6	46	1.204	4.615	0.0010
	Roy's	3	25	0.922	7.687	0.0008

Rings of the greatest width are those laid down in the directions of the south and east (2.26 and 2.17 cm respectively), while they are narrowest where growth is in a northerly direction (at 1.97 cm) (Fig. 3). This found confirmation via the ascribing of the southern and eastern directions to the same homogeneous group (Table 3).

Table 3. Homogeneous groups for key compass directions and measured widths of tree rings. Homogeneous groups: a, b.

Compass direction	Mean	1	2
N	1.973		b
W	2.123	a	b
E	2.180	a	
S	2.268	a	

The aforementioned tendency was observed for trees at Mieszkowice and Wołów, while those from Krosno were characterised by rather even radial growth in all directions (Fig. 4.). The obtained mean values for widths of growth rings correspond with those given for the selected seed stand within Krosno FD [6] – 2.24 cm, while at the same time being much smaller than the 3.4 cm on average noted in Greece [1]. It is true that research done hitherto on the radial growth of the black locust does not contain distinct information on the influence of compass direction on the shaping of ring widths. However, a certain premise explaining the observed differences may be offered by the work of Yang and Murchison [12], Yang and Hazenberg [13] and Waisel and Fahn [14]. The authors of these studies in fact showed – for growth in *Pinus contorta*, *Pinus banksiana* and *Larix laricina* – that rings were significantly wider where growth was in the southern and western directions.

If there is a real link between day length and air temperature when it comes to the initiation of cambial activity, it can then also be presumed that the southern and eastern sides have insolation sufficient to raise trunk temperature and thus indirectly accelerate the division of cells in the cambium. The earlier appearance of conditions optimal for cell division on the southern and eastern sides of the trunk finds its reflection in wider growth rings. And, as was mentioned earlier, this relationship is only present in trees of the Wołów and Mieszkowice populations, while in the youngest of the stands studied – at Krosno – this regularity was not to be observed. That may be associated with the presence of a second stand layer formed by spruce trees that serves to limit the insolation reaching the trunks of the black locust trees.

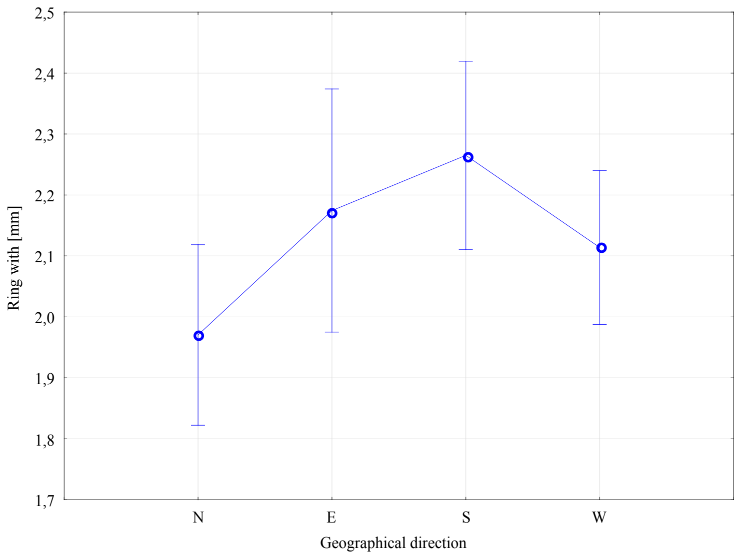

Fig. 3. Mean values for the widths of tree rings in relation to compass directions of growth.

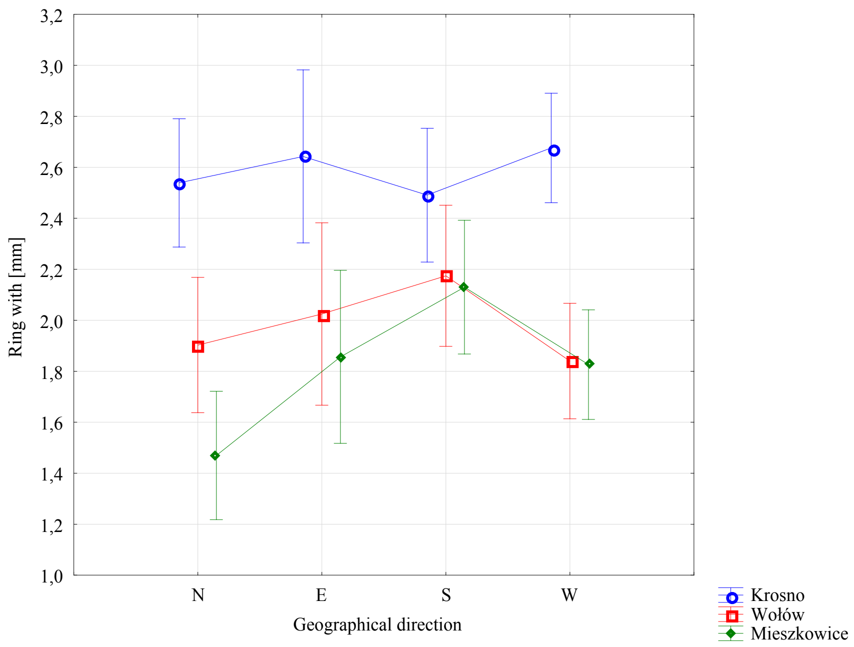

Fig. 4. Mean values for the widths of annual tree rings for the Krosno, Wołów and Mieszkowice sites, as related to direction.

This research project has been funded by the General Directorate of the State Forests (BLP 386).

REFERENCES

1. S. ADAMOPOULOS, E. VOULGARIDIS, Within-tree variation in growth rate and cell dimensions in the wood of Black locust (Robinia pseudoacacia). IAWA Journal, 23 (2), (2002), 191–199,
2. T. BARNA, G. SZULCSÁN, Comparative examination of various clones of the black locust (Robinia pseudoacacia l.). Jour. Engineering Annals of Faculty of Engineering Hunedoara 7 (2009), 195–198,
3. S. D. CHARLES, Statistical Methods for the Analysis of Repeated Measurements. Springer Texts in Statistics. Springer-Verlag, New York, Inc., (2002),
4. O. DINI-PAPANASTASI, Effects of clonal selection on biomass production and quality in Robinia pseudoacacia var. monophylla Carr. Forest Ecology and Management 256 (2008) 849–854,
5. E. FABISIAK, Zmienność podstawowych elementów anatomicznych i gęstości drewna wybranych gatunków drzew. Roczniki Akademii Rolniczej w Poznaniu. Rozprawy Naukowe. 369 (2005), 50–57,
6. E. FELIKSIK, S. ORZEŁ, S. WILCZYŃSKI, Dendrometric and dendroclimatological analyses of Black locust. EJPAU 10 (2007), Available Online: http://www.ejpau.media.pl/volume10/issue2/art-07.html
7. A. HEJNOWICZ, Z. HEJNOWICZ, Variations of length of vessel members and fibres in the trunk of (Robinia pseudoacacia L.). Acta. Soc. Bot. Pol. 28 (1959), 453–460,

8. B. KERESZTESI, Breeding and cultivation of Black locust, Robinia pseudoacacia, in Hungary. Forest Ecology and Management 6 (1983) 217–244,
9. B. KERESZTESI, The Black locust, Akadémiai Kiadó, Budapest, (1988),
10. K. RÉDEI, Z. OSVÁTH-BUJTÁS, I. VEPERDI, Black locust (Robinia pseudoacacia L.) improvement in Hungary: a review. Acta Silv. Lign. Hung., 4 (2008) 127–132,
11. StatSoft, Inc. STATISTICA (data analysis software system), version 10. (2011), www.statsoft.com,
12. K.C. YANG, H.G. MURCHISON, Sapwood thickness in Pinus contorta var. latifolia. Can. Jour. For. Res., 22 (1992) 2004–2006,
13. K.C. YANG, G. HAZENBERG, G.E. BRADFIELD, J.R. MAZE, Vertical variation of sapwood thickness in Pinus banksiana Lamb. and Larix laricina (Du Roi). Can. Jour. For. Res., 15 (1985) 822–828,
14. Y. WAISEL, A. FAHN, The effects of environment on wood formation and cambial activity in Robinia pseudacacia l. Jour. Plant Growth Regulator 64 (1965), 436–442,
15. T. WOJDA, M. KLISZ, M. MIONSKOWSKI, I. SZYP-BOROWSKA, K. SZCZYGIEŁ, Występowanie robinii akacjowej w Polsce oraz badania IBL nad tym gatunkiem. (In:) Robinia akacjowa w krajobrazie Ziemi Lubuskiej. Conference materials, (2014), 22–29.

Streszczenie: *Wzrost promieniowy wyselekcjonowanych drzewostanów robinii akacjowej*. W ramach badań dotyczących właściwości drewna wybranych, prostopiennych populacji robinii pseudoakacji przeprowadzono analizę profili promieniowych w czterech, podstawowych kierunkach geograficznych. Analiza szerokości słoi rocznych wyżynków pobranych z drzew próbnych pozwoliła wyróżnić dwa okresy wzrostu promieniowego różniące się pod względem dynamiki wzrostu. Analiza wariancji potwierdziła istotny wpływ interakcji czynników: lat i populacji na kształtowanie się szerokości słoi rocznych. Jednocześnie u drzew z populacji Wołów i Mieszkowice zaobserwowano wytwarzanie największych przyrostów od strony południowej i wschodniej pni. Prawidłowość ta może być spowodowana inicjującym wpływem długości dnia i temperatury powietrza na początek aktywności kambium u robinii.

Corresponding author:
Forest Research Institute, Department of Silviculture and Genetics,
3 Braci Leśnej Street, Sękocin Stary, 05-090 Raszyn, Poland
E-mail address: kliszm@ibles.waw.pl (Marcin Klisz)